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**MULTI-BAND TRANSCEIVERS WITH REDUCED FREQUENCY SOURCES FOR
20 DIGITAL TRANSMISSIONS**

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TECHNICAL FIELD

This invention relates to the architecture of communications equipment and, more particularly, to a system of minimizing the frequency sources and filters in communications transceivers.

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BACKGROUND OF THE INVENTION

As the cellular and wireless communication industries continue to define themselves, the promulgation of various standards and protocols continue to plague the industry. This plague along with the partitioning of the frequency spectrum has assured the need for dual-band, dual-mode radio transceivers into the foreseeable future.

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Some manufacturers of radio telephone devices have succeeded in providing transceivers that are dual-mode (transceivers that support two or more protocols) and/or dual-band (transceivers that operate in multiple frequency ranges).

5 However, these dual-band, dual-mode transceivers have distinct
disadvantages which are addressed by the present invention.
Early versions of dual-band transceivers included two
transceivers that had the electronic components necessary to
operate in both bands. This was the equivalent of taking two
10 transceivers that operate in different bands and taping them
back-to-back. The inefficiencies of component usage, power
consumption, and the size were unacceptable.

In today's dual-band radio transceivers, the components
of one band are shared to allow the transceiver to work in a
second band. One key to today's technology is to use an
oscillator (frequency source) that may be shifted between a
first and a second frequency range. The frequency range of
the frequency source is primarily a function of the band in
which the transceiver is transmitting or receiving. However,
prior art techniques have not fully reduced the number of
20 oscillators required in a dual-band transceiver to the level
achieved by the present invention. Thus, a first objective of
the present invention is to reduce the component count,
particularly the frequency sources and filters needed in a
25 dual-band transceiver.

In addition to the use of a multiple band frequency
source, a fixed second frequency source is utilized in some of
the techniques provided today. In some prior art
transmitters, the dual-band frequency source generates a first
30 oscillation frequency and the second frequency source
generates a second oscillating frequency. However, prior art
fails to utilize
the two oscillators for all the primary needs in both the
transmitter and the receiver front and back-ends. Thus, it is
35 another objective of the present invention to minimize the
number of frequency sources required for the transmitter and
the receiver front and back-end.

5 SUMMARY OF THE INVENTION

The present invention is a transceiver that can process signals in multiple bands, requiring a reduced number of frequency sources and filters. The dual band transceiver requires only two frequency sources to accomplish the entire 10 front and back-end of the transmitter and receiver section. Thus, one inventive aspect of the present invention is the reduced number of frequency sources. A second inventive aspect is at least one of the frequency sources has an expanded frequency range, enabling the transceiver to handle 15 an increased number of frequency bands. The advantage of the present invention, and the aforementioned inventive aspects, is a reduced number of components (including frequency sources and filters), and cost.

The frequency of the transmit and receive channels are separated by the off-set of the frequency sources. The first frequency source is fed to both the input transmitter mixers, which also receive the I and Q inputs. Each of the transmitter mixers individually combine the first frequency source output and the input signals (unmodulated I and Q 25 transmit signal). The output of the input transmitter mixers are summed together to form a modulated signal (IF transmit signal). The IF transmit signal is the input to a first band and a second band output transmitter mixer. In addition, the second frequency source has a direct electrical connection to 30 the first band output transmitter mixer and is connected to the second band output transmitter mixer through a frequency scaler. If the transceiver is in a first band, the second frequency source signal is combined with the IF transmit signal, resulting in a transmitter output signal (RF transmit 35 signal) corresponding to the first band. However, when the transceiver is operating in the second band, a scaled second frequency source signal is combined with the IF transmit

5 signal by the second band output transmitter. The result is an RF transmit signal corresponding to the second band.

The two frequency sources are also utilized for the receiver section of the transceiver. If the transceiver is operating in a first band, the first band input receiver mixer 10 combines the input signal (RF receive signal) with the second frequency source signal, to obtain a first IF receive signal. If the transceiver is operating in a second band, the second band input receiver mixer combines the RF receive signal with a scaled second frequency source signal, to obtain a first IF receive signal. In another exemplary embodiment, the first IF receive signal is down-converted again to obtain a second IF signal. Finally, the IF receive signal (or second IF receive signal) is combined with the first frequency source signal, to obtain an output receiver signal (unmodulated receive signal). By using a programming means to set the frequency of the first and/or second frequency source, and by using scalers to obtain specific frequencies, the transceiver may operate in both bands.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram 100 that illustrates an exemplary embodiment of the present invention.

Fig. 2 is a detailed schematic diagram 200 illustrating the components and functional blocks necessary in an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

Fig. 1 is a block diagram 100 that illustrates an exemplary embodiment of the present invention, capable of transmitting and receiving in a first and second frequency band. Certain signals which may be present while transmitting and receiving in one band, may not be present while operating

5 in the second band. In implementing the present invention,
there were certain assumptions made about the baseband
processor:

10 1. The baseband can modulate both digital signals and FM
analog signals through the transmitter I and Q inputs
of the modulator. The digital signals can be in the
form of $\Pi/4$ DQPSK, GSM, 8-PSK or any digital modulation
scheme that could be utilized in a TDMA system. This
ability to modulate both digital and FM analog signals
allows the same IF oscillator to be shared between the
receiver and transmitter, since the IF oscillator is
not modulated directly during FM mode.

15 2. Both digital signals and FM analog signals are
demodulated in the quadrature demodulator in the
receiver and outputted through the receiver I and Q
outputs to be further processed by the baseband.

20 3. In digital mode, the RF Phase Locked-Loop (PLL) can be
programmed by the baseband processor to change
frequency between the receive and transmit slots. For
Time Division Multiplexing (TDMA) systems, the receiver
and transmitter do not operate simultaneously and the
RF PLL can change frequency as long as the frequency
is settled before the receive and transmit slots time
periods.

30 The first frequency source 105 is used as the oscillating
source for upconverting the incoming transmit signal which is
applied at the input 139. The incoming transmit signal is a
digitized representation of a voice or data signal. The first
35 frequency source 105 has an output 106 which is electrically
coupled such that its signal is applied at the input 133 of
the back-end transmitter mixer 130. The first frequency
source 105 may be a voltage controlled oscillator (VCO) or
other frequency source capable of providing the frequency
40 necessary for the upconversion of the incoming transmit
signal. The frequency source of this embodiment is stabilized
by a phase-locked loop configuration, which is known to those
skilled in the art.

45 While operating in the first band, the back-end
transmitter mixer 130 upconverts (combines) the incoming

5 transmit signal and the frequency from the first frequency source 105. As is known in the industry, the input 139 to the back-end transmitter mixer 130 may take on a variety of forms but a common form includes an in-phase "I" signal and an out-of-phase "Q" signal. The output 137 of the back-end
10 transmitter mixer 130 is an IF transmit signal. Those skilled in the art will realize the IF transmit may also have been filtered to obtain the necessary frequency for downstream processing. Filtering techniques are known by the skilled artisan, and are not detailed in block diagram 100. Along with
15 the frequency sources, the present invention reduces the number of filters needed by using common transmit and receive IF paths for any band.

The IF transmit signal from the back-end transmitter mixer 130 is electrically coupled to the first input 145 of the front-end transmitter mixer 135. The front-end transmitter mixer 135 also has a second and third input. A second input 111 of the front-end transmitter mixer 135 is electrically coupled to the output 112 of the second frequency source 110. This connection provides the second oscillating
25 signal to the front-end transmitter mixer 135 during operation in the first band. In one embodiment, the second frequency source 110 is programmable, and capable of oscillating over a range of frequencies. While the transceiver is operating in the first band, the front-end transmitter mixer combines the
30 IF transmit signal and the second oscillating signal to obtain a final transmitter frequency corresponding to the first band at the output 147.

When the invention is operating in the second band, the operation is basically similar to the operation in the first
35 band; however, the differences are included below. The back-end transmitter mixer 130 combines the input transmit signal at a first input 139 and the first oscillating signal from the first frequency source 105 at a second input 133 of the back-

5 end transmitter, to generate an IF transmit signal at the
output 137. This IF transmit signal is then provided to the
input 145 of the front-end transmitter mixer 135. When the
transceiver is operating in the second band the output 112 of
10 the second frequency source 110 is passed to the input 141 of
a frequency scaler 115. A scaler is a device that multiplies
or divides a frequency at its input to provide a scaled
frequency output in accordance with its multiplication or
division factor. The signal at the output 143 of the
frequency scaler 115, the scaled second oscillating signal, is
15 provided to the input 119 of the front-end transmitter mixer
135. The front-end transmitter mixer 135 combines the IF
transmit signal and the scaled second oscillating signal, to
generate at its output 147, the final transmitter frequency
corresponding to the second band. Regardless of which band
20 the transceiver is operating in, the front-end transmitter
mixer 135 receives the same IF transmit signal at input 145.

In addition to transmitting in a first and second band,
the transceiver also receives in a first and second band.
While operating in the first band, the second frequency source
25 110 generates the second oscillating signal corresponding with
the first band. The second frequency source 110 has an output
112 which is electrically coupled to a first oscillating input
113 of the front-end receiver mixer 120.

While the transceiver is operating in the first band, the
30 front-end receiver mixer 120 receives the second oscillating
signal from the second frequency source 110 at the first
oscillating input 113. RF receive signals are received at the
RF input 121 of the front-end receiver mixer 120 and are
combined with the second oscillating signal to generate an IF
35 receive signal at output 123.

When the transceiver is operating in the second band, the
second frequency source 110 provides an oscillating signal at
its output 112 to the second oscillating input 117 of the

5 front-end receiver mixer 120 through the scaler 115. The oscillating signal at the output 112 of the second frequency source 110 is electrically coupled to the input 141 of the scaler 115. The output 143 of the scaler 115 is electrically coupled to the second oscillating input 117 of the front-end receiver mixer 120. Thus, the front-end receiver mixer 120 receives the scaled second oscillating signal corresponding to the second band and mixes this oscillating signal with the RF signal to generate an IF receive signal.

10 The IF output 123 of the front-end receiver mixer 120 is electrically coupled to the IF receive input 127 of the back-end receiver mixer 125. If the transceiver is operating in the first band, the back-end receiver mixer 125 receives an IF receive signal generated by combining the second oscillating signal and the RF receive signal. Similarly, if the transceiver is operating in the second band, the back-end receiver mixer 125 receives an IF receive signal generated by combining the scaled second oscillating signal and the RF receive signal. The IF receive signal is the same input to the IF receive input 127, no matter which band the transceiver 15 is operating in at the time.

20 In addition to the IF input 127, the back-end receiver mixer 125 also has an oscillating input 129 electrically connected to the output 106 of the first frequency source 105. Regardless of which band the transceiver is operating, the back-end receiver mixer 125 receives the same IF receive 25 signal at the IF input 127 and combines it with the first oscillating signal at oscillating input 129. The output 131 of the back-end receiver mixer 125 is an unmodulated receiver signal (baseband) corresponding to the appropriate band.

30 It should be noted that other embodiments of this invention could be implemented with formats other than TDMA; including GSM, EDGE, and CDMA formats.

5 Fig. 2 illustrates a detailed schematic diagram 200 of an exemplary embodiment of the present invention. In general, the schematic can be viewed as including a transmitter path 243, a receiver path 245, and two frequency sources 205 and 210. The first frequency source 205 is preferably connected
10 in a phase-locked loop configuration. The first frequency source 205 is also preferably programmable to oscillate at a range of frequencies. Note, the transmitter shown in diagram 200 uses the same transmitter Intermediate Frequency for both bands. In an alternative embodiment, the second frequency source 210 includes a voltage doubler 240 to extend the tuning range of the frequency source. The voltage doubler 240 would be electrically coupled to the output of the RF phase-locked loop 239 and allow the control signal to the second frequency source 210 to have a greater frequency range.

15 The details of figure 200 are best considered by discussing the components which are common to the transmitter path 243 and the receiver path 245. Discussion of the common components will be followed by discussing the first and second band operation of the transmitter path 243, and finally the
20 first and second band operation of the receiver path 245.

25 The first frequency source 205 and the second frequency source 210 are common to the transmitter path 243 and the receiver path 245. The frequency of the first frequency source 205 is maintained by the IF Phase Lock Loop circuitry 241. Similarly, the frequency of the second frequency source 210 is maintained by the RF Phase Lock Loop circuitry 239.

30 The I and Q inputs (baseband) are the inputs to the first transmitter mixer 209 and the second transmitter mixer 211 associated with the transmitter path 243. In addition, the first transmitter mixer 209 and the second transmitter mixer 211 are electrically coupled to the input of a first frequency scaler 207 associated with the transmitter path 243. The first frequency scaler 207 receives a first oscillating signal

5 from the first frequency source **205** and provides a scaled
first oscillating signal to the first transmitter mixer **209**
and the second transmitter mixer **211**. Those skilled in the
art will recognize that the two mixers are in a typical 90
degree phase shift from one another as is standard in
10 processing I and Q components of a signal. Thus, both mixers
will combine their respective transmitter signal inputs with
the scaled first oscillating signal and their respective
outputs will be summed together in summation device **233**. The
summation of the respective first and second transmitter
mixers form an IF transmit signal. Depending on the band of
operation of the transceiver **200**, the IF transmit signal will
be the input to either the third transmitter mixer **213** or the
input of the fourth transmitter mixer **215**. The third
transmitter mixer **213** and the fourth transmitter mixer **215** are
20 used to convert the IF transmit signal to RF.
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The second input to both the third transmitter mixer **213**
and the fourth transmitter mixer **215**, is the second
oscillating signal, which is the output of the second
frequency source **210**. The second frequency source **210** is
25 preferably a programmable frequency source with a capability
to oscillate in a range of frequencies.

As previously mentioned, the transceiver **200** can operate
in multiple bands, referred to for convenience as a first band
and a second band. While operating in the first band, the
30 path for converting the IF signal to an RF signal includes a
third transmitter mixer **213**. The third transmitter mixer **213**
will combine the IF signal with the second oscillating signal
from the second frequency source **210**. During operation in the
first band, the fourth transmitter mixer **215** is disabled.
35 Skilled artisans may use one of several common techniques to
disable the fourth transmitter mixer **215** at the appropriate
time, but the present invention is not concerned with details
of which technique is used. The output **235** of third

5 transmitter mixer **213** is an RF transmit signal corresponding to the first band. This RF signal may be subsequently provided to antenna circuitry (not shown) for transmission.

10 Similarly, if the transceiver **200** is operating in a second band, the second oscillating signal from the second frequency source **210** is the input to the fourth transmitter mixer **215**, through a second frequency scaler **217**. The input to the second frequency scaler **217** is the second oscillating signal from the second frequency source **210**. The output of the second frequency scaler **217** is a scaled second oscillating signal, which is the input to the fourth transmitter mixer **215**. The fourth transmitter mixer **215** will combine the IF transmit signal with the scaled second oscillating signal. The output **235** of the fourth transmitter mixer **215** is an RF transmit signal corresponding to the second band.

20 As previously described, in addition to the capability of transmitting in a first and second band, the transceiver is capable of receiving in a first and second band. The first receiver mixer **219** and second receiver **221** mixer are located in the receiver path **245**, and are used for converting the RF to IF. The second frequency source **210** is electrically connected to the both the first receiver mixer **219** and second receiver mixer **221**. However, the second frequency source **210** is electrically coupled to the second receiver mixer **221** through a second frequency scaler **217**. In addition, both the first receiver mixer **219** and second receiver mixer **221** have an RF input **237**, and their respective outputs are electrically coupled to the first input of a third receiver mixer **223**.

30 When the transceiver **200** is operating in the first band, the second frequency source **210** has an output of a second oscillating signal. The second oscillating signal is the input to the first receiver mixer **219**; however, if necessary the second oscillating signal may be scaled. In addition, the first receiver mixer **219** receives an RF incoming signal **237** on

5 a second input. The first receiver mixer **219** combines the RF incoming signal **237** and the second oscillating signal. The output of the first receiver mixer **219** is a first receiver IF. Thus, the first receiver IF is the input to the third receiver mixer **223**.

10 However, when the transceiver **200** is operating in the second band, the output of the second frequency source **210**, a second oscillating signal, is connected to the input of the second frequency scaler **217**. The output of the second frequency scaler **217** is a scaled second oscillating signal. Thus, the scaled second oscillating signal is the input to the second receiver mixer **221**. In addition, the second receiver mixer **221** receives an RF incoming signal. The second receiver mixer **221** combines the RF incoming signal and the scaled second oscillating signal. The output of the second receiver mixer **221** is the first receiver IF, which is connected to the third receiver mixer **223**. Thus, the input to the third receiver mixer **223** is the first receiver IF. It should be noted that the first receiver mixer **219** is not operational when the transceiver **200** is operating in the second band, nor is the second receiver mixer **221** operational while the transceiver **200** is operating in the first band.

15 In addition to receiving the first receiver IF signal, the third receiver mixer **223** also has a second input which is electrically connected to the first frequency source **205**, through a third frequency scaler **225**. The first frequency output of the first frequency source **205** is the input to the third frequency scaler **225**. The output of the third frequency scaler **225** is a scaled first oscillating signal. Thus, the scaled first oscillating signal is the second input of the third receiver mixer **223**.

20 The third receiver mixer **223** combines the scaled first oscillating signal and the first receiver IF signal, regardless of which band the transceiver **200** is operating in

5 at the time. The output of the third receiver mixer 223, is a second receiver IF, electrically connected to the fourth receiver mixer 227 and the fifth receiver mixer 229.

10 The fourth receiver mixer 227 and fifth receiver mixer 229 are 90 degrees out of phase with one another and arranged in the common form of in-phase "I" signal and an out-of-phase "Q" signal, which is known by the skilled artisan. Thus, further details of the I and Q arrangement are herein omitted.

15 A second input to the fourth receiver mixer 227 and fifth receiver mixer 229 is a scaled first oscillating signal from the first frequency source 205 through a fourth frequency scaler 231. The input to the fourth frequency scaler 231 is the first oscillating signal from the first frequency source 205 and its output is a scaled first oscillating signal which is the input to the fourth receiver mixer 227 and fifth receiver mixer 229. When the transceiver 200 is functioning in either the first or second band, the fourth receiver mixer 227 and the fifth receiver mixer 229 each individually receive and combine the second receiver IF (received from the third receiver mixer 223) and the scaled first oscillating signal (received from the output of the fourth frequency scaler 231). The fourth receiver mixer 227 and the fifth receiver mixer 229 produce an unmodulated receive signal (baseband) on their respective receiver I and Q outputs, which may be further processed in the baseband processor (not shown).

20 30 Alternate embodiments will become apparent to those skilled in the art to which the present invention pertains without departing from its spirit and scope. Accordingly, the scope of the present invention is described by the appended claims and supported by the foregoing description.